

**02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and
co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS**

Submit only ONE copy of this form for each PI/PD and co-PI/PD identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. **DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.**

PI/PD Name: Duncan Sibley

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☐

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:

Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.

Race Definitions:

American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.

Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.

Black or African American. A person having origins in any of the black racial groups of Africa.

Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information received from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational opportunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

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PI/PD Name: Julie C Libarkin

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
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☐ Other
☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Mark Urban-Lurain

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☒ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
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☒ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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PI/PD Name: Dedre Gentner

Gender: ☐ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
☐ White

Disability Status:
(Select one or more)

☐ Hearing Impairment
☐ Visual Impairment
☐ Mobility/Orthopedic Impairment
☐ Other
☐ None

Citizenship: (Choose one) ☐ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:

Not Listed

REVIEWERS NOT TO INCLUDE:

Not Listed

List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:

Not Listed

REVIEWERS NOT TO INCLUDE:

Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 09-29					FOR NSF USE ONLY		
NSF 09-529			05/21/09			NSF PROPOSAL NUMBER	
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)					0941492		
DUE - CCLI-Phase 1: Exploratory							
DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION		
05/20/2009	2	11040000 DUE	7494	193247145	06/30/2009 2:03pm S		
EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)		SHOW PREVIOUS AWARD NO. IF THIS IS <input type="checkbox"/> A RENEWAL <input type="checkbox"/> AN ACCOMPLISHMENT-BASED RENEWAL		IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/> IF YES, LIST ACRONYM(S)			
386005984							
NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE			ADDRESS OF Awardee ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE				
Michigan State University			CONTRACT AND GRANT ADMINISTRATIO				
AWARDEE ORGANIZATION CODE (IF KNOWN)			301 ADMINISTRATION BUILDING				
0022905000			EAST LANSING, MI 48824-1046				
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE			ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE				
PERFORMING ORGANIZATION CODE (IF KNOWN)							
IS Awardee ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)							
<input type="checkbox"/> SMALL BUSINESS <input type="checkbox"/> MINORITY BUSINESS <input type="checkbox"/> IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE <input type="checkbox"/> FOR-PROFIT ORGANIZATION <input type="checkbox"/> WOMAN-OWNED BUSINESS							
TITLE OF PROPOSED PROJECT Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning							
REQUESTED AMOUNT \$ 93,850		PROPOSED DURATION (1-60 MONTHS) 24 months		REQUESTED STARTING DATE 01/01/10		SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE	
CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW							
<input type="checkbox"/> BEGINNING INVESTIGATOR (GPG I.G.2) <input checked="" type="checkbox"/> HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number 00004556 <input type="checkbox"/> DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e) Exemption Subsection _____ or IRB App. Date 01/01/10 <input type="checkbox"/> PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d) <input type="checkbox"/> INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) <input type="checkbox"/> HISTORIC PLACES (GPG II.C.2.j) <input type="checkbox"/> EAGER* (GPG II.D.2) <input type="checkbox"/> RAPID** (GPG II.D.1) <input type="checkbox"/> VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____ PHS Animal Welfare Assurance Number _____							
PI/PD DEPARTMENT Center Research College Science T&L			PI/PD POSTAL ADDRESS 213 North Kedzie				
PI/PD FAX NUMBER			East Lansing, MI 488241115				
			United States				
NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address			
PI/PD NAME Duncan Sibley	PhD	1975	517-432-6529	sibleybr@msu.edu			
CO-PI/PD Julie C Libarkin	PhD	1999	517-355-8369	libarkin@msu.edu			
CO-PI/PD Mark Urban-Lurain	PhD	2000	517-432-2152	urban@msu.edu			
CO-PI/PD							
CO-PI/PD							

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 09-29). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes ☐

No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

- (1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
- (2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.
- (3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

- (1) community in which that area is located participates in the national flood insurance program; and
- (2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

- (1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
- (2) for other NSF Grants when more than \$25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE		SIGNATURE		DATE	
NAME		Electronic Signature		May 20 2009 3:33PM	
TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS			FAX NUMBER	
517-355-5040	flanner@cga.msu.edu			517-353-9812	

* EAGER - Early-concept Grants for Exploratory Research

** RAPID - Grants for Rapid Response Research

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NSF 09-529 05/21/09					NSF PROPOSAL NUMBER	
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.)					0942099	
DUE - CCLI-Phase 1: Exploratory						
DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION	
05/21/2009	2	11040000 DUE	7494	160079455	06/30/2009 2:04pm S	
EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)		SHOW PREVIOUS AWARD NO. IF THIS IS <input type="checkbox"/> A RENEWAL <input type="checkbox"/> AN ACCOMPLISHMENT-BASED RENEWAL		IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES <input type="checkbox"/> NO <input checked="" type="checkbox"/> IF YES, LIST ACRONYM(S)		
362167817						
NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE Northwestern University			ADDRESS OF Awardee ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE Northwestern University 633 Clark Street Evanston, IL. 602081110			
AWARDEE ORGANIZATION CODE (IF KNOWN) 0017392000						
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE			ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE			
PERFORMING ORGANIZATION CODE (IF KNOWN)						
IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)		<input type="checkbox"/> SMALL BUSINESS <input type="checkbox"/> FOR-PROFIT ORGANIZATION		<input type="checkbox"/> MINORITY BUSINESS <input type="checkbox"/> WOMAN-OWNED BUSINESS		<input type="checkbox"/> IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE
TITLE OF PROPOSED PROJECT Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning						
REQUESTED AMOUNT \$ 106,092	PROPOSED DURATION (1-60 MONTHS) 24 months		REQUESTED STARTING DATE 01/01/10		SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE	
CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW <input type="checkbox"/> BEGINNING INVESTIGATOR (GPG I.G.2) <input type="checkbox"/> DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e) <input type="checkbox"/> PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d) <input type="checkbox"/> HISTORIC PLACES (GPG II.C.2.j) <input type="checkbox"/> EAGER* (GPG II.D.2) <input type="checkbox"/> RAPID** (GPG II.D.1) <input type="checkbox"/> VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date _____ PHS Animal Welfare Assurance Number _____ <input type="checkbox"/> HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number _____ Exemption Subsection _____ or IRB App. Date _____ <input type="checkbox"/> INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) _____ <input type="checkbox"/> HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)						
PI/PD DEPARTMENT Department of Psychology		PI/PD POSTAL ADDRESS 2029 Sheridan Road Evanston, IL 60208 United States				
PI/PD FAX NUMBER 847-491-7859						
NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address		
PI/PD NAME Dedre Gentner	PhD	1974	847-467-2035	gentner@northwestern.edu		
CO-PI/PD						
CO-PI/PD						
CO-PI/PD						
CO-PI/PD						

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the Authorized Organizational Representative or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), nondiscrimination, and flood hazard insurance (when applicable) as set forth in the NSF Proposal & Award Policies & Procedures Guide, Part I: the Grant Proposal Guide (GPG) (NSF 09-29). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

Conflict of Interest Certification

In addition, if the applicant institution employs more than fifty persons, by electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.A; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency?

Yes ☐

No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

The following certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding \$100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding \$150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

- (1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.
- (2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure of Lobbying Activities," in accordance with its instructions.
- (3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than \$10,000 and not more than \$100,000 for each such failure.

Certification Regarding Nondiscrimination

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:

- (1) community in which that area is located participates in the national flood insurance program; and
- (2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:

- (1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
- (2) for other NSF Grants when more than \$25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE		SIGNATURE		DATE	
NAME		Electronic Signature		May 21 2009 5:49PM	
TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS		FAX NUMBER		
847-467-1967	tnewman@northwestern.edu		847-491-4800		

* EAGER - Early-concept Grants for Exploratory Research

** RAPID - Grants for Rapid Response Research

NATIONAL SCIENCE FOUNDATION
Division of Undergraduate Education

NSF FORM 1295: PROJECT DATA FORM

The instructions and codes to be used in completing this form are provided in Appendix II.

1. **Program-track** to which the Proposal is submitted: CCLI-Phase 1: Exploratory
2. Name of **Principal Investigator/Project Director** (as shown on the Cover Sheet):
Sibley, Duncan
3. Name of submitting **Institution** (as shown on Cover Sheet):
Michigan State University
4. **Other Institutions** involved in the project's operation:
Northwestern Univeristy

Project Data:

- A. Major Discipline Code: 99
- B. Academic Focus Level of Project: LO
- C. Highest Degree Code: D
- D. Category Code: --
- E. Business/Industry Participation Code: NA
- F. Audience Code: WMT _ _ _ _ _
- G. Institution Code: PUBL
- H. Strategic Area Code: EN
- I. Project Features: C _ _ _ _ _

Estimated number in each of the following categories to be directly affected by the activities of the project during its operation:

- J. Undergraduate Students: 200
- K. Pre-college Students: 0
- L. College Faculty: 0
- M. Pre-college Teachers: 0
- N. Graduate Students: 1

NATIONAL SCIENCE FOUNDATION
Division of Undergraduate Education

NSF FORM 1295: PROJECT DATA FORM

The instructions and codes to be used in completing this form are provided in Appendix II.

1. **Program-track** to which the Proposal is submitted: CCLI-Phase 1: Exploratory
2. Name of **Principal Investigator/Project Director** (as shown on the Cover Sheet):
Gentner, Dedre
3. Name of submitting **Institution** (as shown on Cover Sheet):
Northwestern University
4. **Other Institutions** involved in the project's operation:

Project Data:

- A. Major Discipline Code: 73
- B. Academic Focus Level of Project: BO
- C. Highest Degree Code: D
- D. Category Code: --
- E. Business/Industry Participation Code: NA
- F. Audience Code:
- G. Institution Code: PRIV
- H. Strategic Area Code:
- I. Project Features: RA

Estimated number in each of the following categories to be directly affected by the activities of the project during its operation:

- J. Undergraduate Students: 200
- K. Pre-college Students: 0
- L. College Faculty: 0
- M. Pre-college Teachers: 0
- N. Graduate Students: 0

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Project Summary

Intellectual merit. We propose a Type I project that addresses two CCLI project components. In particular, we will: 1) **create new learning materials and strategies** to foster students' **ability to reason by analogy about global climate change** and 2) **assess student ability to use analogies** to make and evaluate claims about global climate. We will test the hypothesis that we can dramatically improve non-science majors' climate change literacy through explicit instruction about analogical reasoning in a general education-science course on Global Change. We focus on analogical reasoning because: 1) analogical reasoning is central in higher-level learning; 2) analogies are commonly used by scientists to convey information about complex systems responsible for global climate change; and 3) scientists routinely use analogies to generate hypotheses and to solve research problems.

The PI (Sibley), through his work as former director of Michigan State University's general education science program and current director of the Center for Research on College Science Teaching and Learning, is acutely aware of the need for more effective pedagogies. Co-PI Gentner is the leading expert on analogical reasoning. Combining her expertise in cognitive science with Libarkin (Co-PI), a national leader in geoscience education research, and Urban-Lurain (Co-PI), an expert in data analysis and technology applications, provides the expertise to successfully carry out the proposed research.

We will *develop new instructional materials and assessment instruments* based on cognitive scientists' understanding of analogical reasoning. In particular, we will help students understand analogies and improve their analogical reasoning by focusing on five dimensions of analogical reasoning suggested by decades of research; retrieval, mapping, evaluation, abstraction and re-representation (Gentner and Colhoun, in press). Successful demonstration of this approach will provide a new, detailed model of how to teach analogical reasoning. In turn, we suggest that facility with analogical reasoning will enhance our students' ability to reason about the complex and dynamic concepts integral to understanding global climate change.

Broader impacts. Addressing global climate change is one of President Obama's major policy initiatives. In his first address to congress, he stated, "We have to save our planet". In our democratic society, we expect the public to play a role in reasoned debate about causes and effects of global climate change and the actions or inactions societies may make in response. Our instructional materials, designed to improve general education students' ability to reason about global climate change, *will address this societal need* because general education science courses in our colleges and universities play a major role in U.S. public scientific literacy (Miller 2007, Hobson 2008).

Scientists use complex models and analogies to reason about climate, including analogies that help our understanding of systems, reservoirs, feedbacks, probability, deep time, and spatial dimensions from the molecular to the global. Although the vast majority of citizens would find mathematical models daunting, we propose that *STEM educators can help students understand and reason with analogies to build global change understanding*.

Our work, *focused on a large general education class for non-majors*, provides the opportunity to investigate the extent to which these instructional materials foster analogical reasoning in non-science majors. Because non-majors courses have more underrepresented groups than most courses for science majors at our university, we will be able to determine the efficacy of the instructional materials with these groups. The materials will also be *useful for K-12 teachers and educators in informal settings* who want to help the public understand the science behind issues of global change, as well as for *science majors* who must learn to communicate through both scientific analogies and models.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.B.2.

	Total No. of Pages	Page No.* (Optional)*
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Project Summary (not to exceed 1 page)	1	_____
Table of Contents	1	_____
Project Description (Including Results from Prior NSF Support) (not to exceed 15 pages) (Exceed only if allowed by a specific program announcement/solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	15	_____
References Cited	4	_____
Biographical Sketches (Not to exceed 2 pages each)	6	_____
Budget (Plus up to 3 pages of budget justification)	4	_____
Current and Pending Support	6	_____
Facilities, Equipment and Other Resources	1	_____
Special Information/Supplementary Documentation	0	_____
Appendix (List below.) (Include only if allowed by a specific program announcement/ solicitation or if approved in advance by the appropriate NSF Assistant Director or designee)	_____	_____
Appendix Items:		

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

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PROJECT DESCRIPTION: BUILDING GLOBAL CLIMATE CHANGE LITERACY THROUGH ANALOGICAL REASONING

1. INTRODUCTION

The problem: Global climate change is widely addressed in public discourse and political commentary. A scientifically literate populace is needed if we are to make rational democratic decisions about the many issues associated with global change, but studies to date suggest the public is not prepared. Results of a recent survey of more than 1100 U.S. adults indicates an awareness of greenhouse warming on the part of the general public but this awareness likely represents a shift in opinion more than in scientific understanding (Miller, personal communication). For example, approximately 72% agree that greenhouse gases are causing global temperatures to rise but an equal percentage think alternative fuels are likely to replace fossil fuels in the next twenty years. Similar work (e.g., Walsh 2008, Sterman 2008) suggests that the public appears to be aware that catastrophic, human induced global climate change is a real possibility but they have little understanding of the basic science supporting this claim.

Scientists invoke analogies in an attempt to help novices understand the science behind global climate change. The greenhouse is one of the most commonly invoked explanations of Earth's climate found in education and the media. Other analogies employed to help experts and non-experts understand climate change include a tipping canoe analog for a climate threshold (Alley 2004), comparisons between CO₂ concentrations and atmospheric temperature to water rising in a bathtub (e.g., Walsh 2008), and the conveyor belt analog for thermohaline circulation (Broecker 1991). Although scientists have always used analogies to explain complex concepts to novices, we do not have curricula specifically designed to help students evaluate, use and build analogies.

Analogies play such a significant role in human cognition that cognitive scientists have developed an entire subfield of study devoted to analogy. Decades of research provide us with significant insight into how experts build and think with analogies, as well as the potential analogies can have for complex learning. Scientists themselves rely heavily on analogy in their own discourse (Sibley, in revision), particularly when discussing complex and non-linear systems, such as global climate.

A solution: Given the fundamental role that analogy plays in everyday and technical reasoning, we propose that a scientifically literate populace must understand scientific analogies. We will apply cognitive and learning science research findings in a college classroom, through development of analogy-based curricula and assessment of student reasoning (Fig. 1). Our work is grounded in science education (Libarkin is an expert) and cognitive science (Gentner is an expert who specializes in analogies), both in relation to curriculum development and in terms of analytical approaches that will be applied to investigating student reasoning. We hypothesize that students will develop the ability to reason about simple global change models by using analogies.

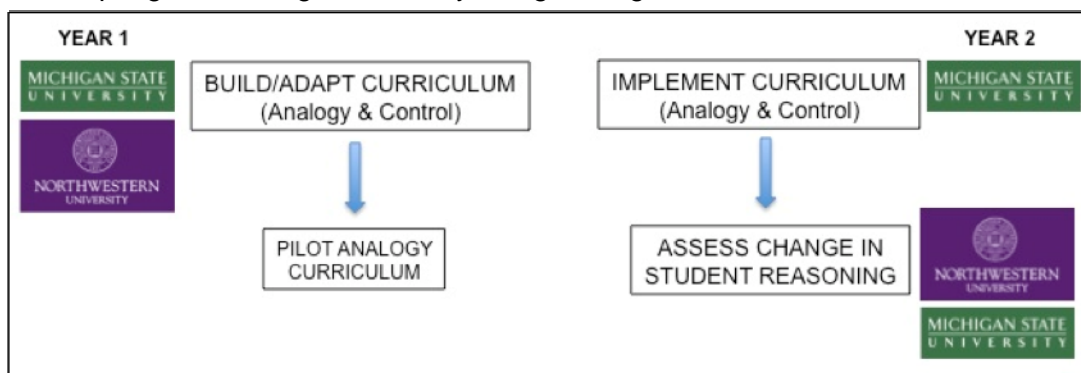


Figure 1. Schematic of project plan. Year 1: Development and piloting of analogy and control curriculum. Year 2: Implementation and assessment of curriculum.

2. GLOBAL CHANGE AND SCIENCE EDUCATION RESEARCH

Although global climate change has been an important classroom concept for several decades, science educators are only now beginning to understand the unique conceptual models that are required to fully understand climate phenomena (Ben-zvi-Assarf and Orion 2005, Safayeni et al. 2005, Herbert 2006, Raia 2008,). Students generally have little understanding of important concepts such as systems, feedback, homeostasis, non-linearity, energy flow, water vapor as a greenhouse gas, or the different time and space scales over which climate change occurs. Libarkin and Kurdziel (2006) found that most college students do understand that objects at the Earth's surface can change over time and vary spatially. However, only a small subset of students recognized that processes at the Earth's surface have underlying causes. This has important implications for teaching complex phenomena that intrinsically rely on an understanding of system dynamics, such as feedback.

A number of studies have identified a range of misconceptions that students have about weather, climate, and climate change. For example, over 30% of 1000 college students nationwide believed that clouds were empty vessels that filled up with water (Libarkin 2006). Students relate the greenhouse effect to the ozone hole, or believe that greenhouse gases are "bad" rather than necessary for moderating Earth's climate (Rebich and Gautier 2005). Gautier et al. (2006) demonstrated that some college students have misconceptions about the interactions between long and short wave length radiation and greenhouse gases. Sibley et al. (2007) showed students have difficulty understanding phase changes in the water cycle and chemical change in the carbon cycle. Preliminary data (Sibley unpublished) from interviews with sophomore science majors indicates that they understand the biosphere-atmosphere portion of the carbon cycle but they are largely unaware of the roles of the hydrosphere and lithosphere yet these are the largest carbon reservoirs.

Computational models such as simple cellular automata and STELLA are very useful platforms for students to practice modeling earth systems (Bice 2006, Turcotte 2006) but would be hard to implement in a large lecture class for non-science majors and difficult to broadly disseminate to many colleges and universities. Cause-MaP (Clark et al. in press) is a new method to help students organize systems into reservoirs and events and to scaffold recognition of transformations that occur in Earth systems and the causes driving transformative processes that generate global change (Clark et al. in press). Cause-MaP is an effective tool for organizing content but does not directly address the issue of students' ability to reason about complex systems.

3. ANALOGICAL REASONING

We contend that analogical reasoning is the driving force behind human thinking and therefore propose analogy as an integrating framework for the variety of human-level reasoning mechanisms. -Schwering et al., 2008

3.1. Analogies

Multiple definitions of the term "analogy" are a part of the vernacular. In the structure-mapping framework (Gentner 1983, 2003; Holyoak 2005) commonly used in cognitive science, an analogy is defined as a pattern of shared relationships among elements in the domain of study (the **target**) and the well-understood domain (the **source** or **base**). The elements of the source and target need not be similar (although novices find analogies easier to process when they are).

We combine Toulmin et al.'s (1984) structure of argument with research in cognitive science (e.g., Johnson-Laird 2006, Schwering et al. 2008) and science education (e.g., Driver et al. 2000, Redish 2004, Berland and Reiser 2009) to recognize common characteristics of students' and experts' reasoning (Table 1). There are other ways to characterize reasoning. Our choice is based on our goal for students to be able to make and evaluate claims about global change. In this framework, *to reason by analogy means using analogies for warrants and backings to support claims*. This operational definition of reasoning permits one to judge reasoning by the validity of claims the reasoner makes and whether or not the support for the claims is appropriate and correct. **Warrants** are rationale for making claims. Depending on the nature of the argument warrants can be ethical norms, rules of thumbs or scientific principles. **Backings** are the rational for accepting the validity of a warrant in a particular context. Analogies may be used both as warrants and backings.

Characteristics of Novices	Characteristics of Experts
<ol style="list-style-type: none"> 1. Reason from isolated facts. 2. Do not distinguish between cause and effect during argumentation. 3. Lack specific reasoning to prove support that a claim is true (warrants). Novices use personal experience rather than scientific principles as warrants. 4. Refer to valid scientific warrants but are unable to provide grounds for the warrants. 5. Make claims, or hold opinions, that are unrelated to facts, cause and effect, grounds, or warrants. 	<ol style="list-style-type: none"> 1. Reason from facts that are related to processes. 2. Relate cause and effect in argumentation. 3. Refer to scientific analogs, models and principles as warrants for claims. Experts use scientific principles as warrants. 4. Provide backing for warrants. 5. Make claims, or hold opinions, that are based upon facts/processes, cause and effect, grounds, or principled warrants.

TABLE 1. Characteristics of novice and expert argumentation.

We focus specifically on analogical reasoning processes because 1) analogical reasoning is fundamental to human cognition (Lakoff and Johnson 1980, Hofstadter 2001, 2007, Gentner 2003, Holyoak 2005, Pinker 2007, Penn et al. 2008); 2) analogical reasoning encourages expert-like thinking (Richland et al. 2007); 3) many scientific models are analogs (Hesse, 1966, 2000) or are used to generate analogs that scientists apply to understanding natural systems (Schumm 1991, Dunbar 2000, Frodeman 1995, Brookes and Etkina 2007); 4) scientists routinely use analogies to generate hypotheses and to solve research problems (Dunbar 2000); and 5) analogies are a major source of intellectual creativity (Hofstadter 2001, Root-Bernstein and Root-Bernstein 1991).

Five cognitive processes are involved in analogical reasoning (Table 2). **Retrieval** is the step in which a current situation reminds someone of a prior situation. Most such retrievals are quite mundane: for example, a boiling kettle reminds us of another boiling kettle (Forbus et al. 1995). But occasionally retrieval provides the spark of genius we associate with a novel analogy. In the proposed study, retrieval is a minor goal because we think it important to first demonstrate that we can affect the other four processes before we experiment with enhancing retrieval. If students cannot succeed in the other four processes, retrieval is not useful. **Mapping** is the process whereby the two domains are aligned and specific commonalities and differences emerge (Gentner and Markman 1997). This is the most important process in this study. Based on cognitive theory, we believe that we can design instructional activities to foster mapping. Mapping is also important because it is a core cognitive process in analogical reasoning, including testing formal scientific models. Mapping is also where reasoning intersects with content knowledge. One must know or learn characteristics of the target and source before one can compare similarities and differences. Because scientific analogies are most useful when the relationships are causal, successful mapping requires one to search for causal similarities rather than simply physical similarities. **Evaluation** is the critical

examination of the commonalities and differences, and especially of the inferences generated by an analogy. At least three criteria influence evaluation: (1) the structural consistency of the analogical mapping; (2) the plausibility of any new inferences in the target domain (for example, if the analogy makes an inference that is clearly false, this is reason to reject the analogy); and (3) the relevance of the inferences to the problem at hand (Gentner 1989). Evaluation involves the application of the knowledge organization from mapping onto an instance. When mapping is done based on causal relationships, evaluation is hypothesis testing. During evaluation one asks the question, “Does the presumed process which is active in the source explain effects observed in the target?” Of course, this presumes one understands causation in the source and understands the conditions under which the process may act in the target. Novices often have very limited understanding of fundamental physical, chemical and biological processes and this makes evaluation difficult. For example, a novice might readily learn that melting involves breaking bonds and therefore requires energy but find it very difficult to explain why the temperature of water does not change during a phase change.

COGNITIVE PROCESSES	EXPLANATION OF TERMS (after Gentner and Colhoun, in press)
Retrieval	A source (analog) similar to the target must be retrieved from long-term memory.
Mapping	Alignment of representational structures of the target and source to derive similarities and differences. This step includes making tentative inferences about the target based on the analog.
Evaluation	Judgments are made about the usefulness and validity of the inferences that derive from the analogy.
Abstraction	Development of generalizations about the category to which source and target belong.
Re- Representation	Alteration of the representation of either the source or the target to improve the usefulness of the analogy.

TABLE 2. Five cognitive processes involved in building an analogy

Successful evaluation requires that one understand the causal principle being applied to the source. When the process of evaluation is deemed successful, then the process of **abstraction** directly follows. Successful mapping of causal principles active in the source and target indicates that one understands how those principles may be applied is generalized and therefore, the causal principle becomes more abstract. **Re-representation** occurs when evaluation and abstraction changes one’s mental representation of the process that affects the target and analog. For example, a student may have a very concrete mental representation of energy as the ability to do mechanical work, which may become more abstract when the concept is expanded to include energy flow associated with chemical reactions. Learning includes, but is not limited to evaluation and re-representation. Hofstadter (2001) takes the radical position that all learning involves drawing analogies. We take the conservative stance that it is very important, particularly in science.

3.2 Analogies and Science Education

Although science educators have written extensively about instructor-generated analogies (Duit 1991, Glyn 1991, Lawson 1993, Treagust et al. 1996, etc), none of the previous studies have explicitly employed all five cognitive processes (Table2) in their instructional materials. In a study of 5th graders and spontaneously generated analogies, Atkins (2004) recognized the role of category building in analogy use, and suggests that analogies can be used to reveal categories that students use to make sense of the world. Sandifer (2004) also investigated

spontaneous generation of analogies, this time by college students enrolled in physics. This work indicates that college students have the same difficulty generating and using analogies as younger children; in particular, a strong understanding of the analog, and a familiarity with target, are necessary prerequisites to effective analogy generation and use.

In one of the few studies of its kind, Pittman (1999) guided 7th and 8th graders working in groups to build extended analogies using 10 key words related to protein synthesis. Students were told to use verbs and one analog such as a city, factory or shopping mall. As a result the analogies students created were rich descriptive stories. Descriptive stories may help students remember characteristics of new objects but to understand causation requires the productive process-based analogies scientists employ (Dunbar 2000). James and Scharmann (2007) trained 45 pre-service elementary teachers in two workshops (the first for 75 minutes and a second for 50 minutes) to develop explanatory analogs about force and motion. Half the students spent 15 minutes learning about and developing analogies and were instructed to pay particular attention to similarities and differences between the analog and target. Small learning gains as measured by students' answer to the Force Concept Inventory are only suggestive of the potential of this approach. James and Scharmann (2007, p. 581) ask, "If 15 minutes of analogy-based instruction could produce a statistical effect 7 weeks after instruction, what sort of effect could be realized in an entire course based on analogy". We intend to find out.

4. PRELIMINARY WORK

During fall 2008, and prior to collaborating with co-PI Gentner, the PI (Sibley) introduced analogical reasoning to 180 non-science majors enrolled in a general education Global Change class. The results of this intervention were only partially successful, but some findings discussed below are useful for formulating the proposed project. One major shortcoming of this preliminary intervention was a focus on students' ability to retrieve analogs. Based on our preliminary results, we think retrieval is a significant leap for most students and a more focused effort on mapping and evaluation will be more beneficial to students.

During a Fall 2008 course, students were asked to retrieve analogies about processes in the water, rock and carbon cycles, and were given practice building analogies during in-class exercises and as online homework assignments. Students' descriptions of similarities between source (analog) and target were classified as causal or non-causal by two investigators. The two investigators agreed on ~90% of the classifications. A similarity was considered causal if it involved a causal relationship or similar effect. Statements of importance or physical similarities were classified as non-causal. Also, restatements of the question were classified as non-causal. For example, "condensation is like evaporation, they are both a part of the water cycle" is non-causal. "Condensation is like freezing because they are both phase changes that release energy when bonds are formed" is causal. Another example of a non-causal statement is "photosynthesis is like a factory because both produce a product". The statement "photosynthesis is like evaporation because both are driven by solar energy" is causal. The data show that for all but one topic, photosynthesis, less than 30% of the students were able to retrieve an analogy that which they could describe as having causal similarities to the target (Figure 2). This low success rate is one reason we decided to focus this project on helping students map and evaluate analogies that have causal similarities. The percentage of students who wrote causal similarities between analogs and targets for six online questions increased throughout the semester from targets early in the semester such as condensation and subduction to targets late in the semester such as degassing and carbon cycle. The data are consistent with the hypothesis that students become better at retrieving analogs with practice. The data also suggest a *potentially* strong relationship between the particular target and whether or not students recognize causal similarities as evidenced by the fact that students described a significantly higher percentage of causal similarities when the target was photosynthesis. We will attempt to verify this relationship in the proposed study with semi-

structured interviews and data on student responses to knowledge and comprehension test questions. As described in section 2, mapping requires content knowledge so students are expected to be more successful mapping causal similarities for those topics for which they have more content knowledge.

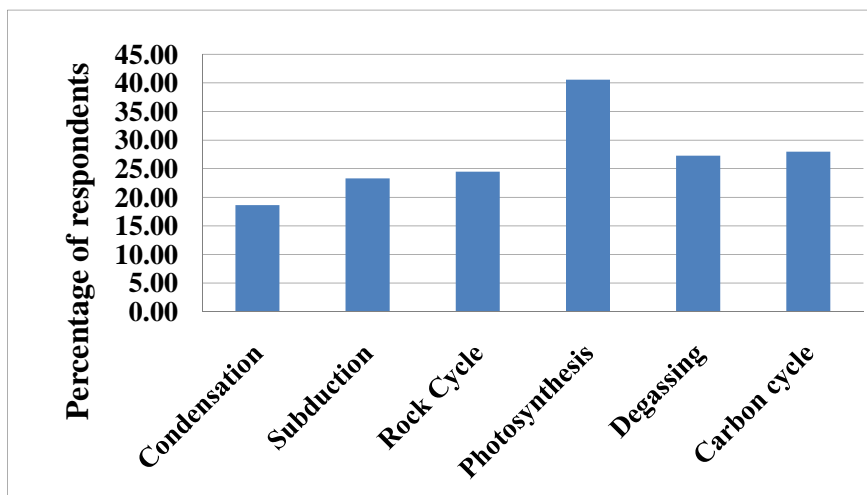


FIGURE 2. Students were asked to generate analogies for six concepts. Between 15% and 40% of students used causal principles to explain similarities between target concepts and the analogs they chose. The students were presented the targets throughout the semester with those on the left (i.e. condensation) at the beginning of the semester and those on the right toward the end of the semester.

Students' online homework responses were downloaded into *SPSS Text Analysis for Survey's* software to facilitate analyses. This software is designed to classify written text into categories. The software provides several options that allow users to control the classification techniques and save custom libraries for particular domains or question categories. It has two ways to create categories: by linguistic analysis using semantic networks, term co-occurrence and term inclusion and exclusion; and by term or type frequency. The standard libraries provided with the software do not recognize most of the technical lexicon of scientific disciplines; therefore it was necessary to build custom lexical libraries with those terms, as well as synonyms, abbreviations, and spelling variations or misspellings. After we created a set of custom libraries, the software extracted key words from students' responses. The key words were classified into *categories* that we created, so that each response was classified into one or more categories. As with any categorization process, the choice of characteristics (in this case terms and phrases) used to categorize responses must be chosen inductively and evaluated empirically. We reformed criteria for categories until the software groupings were consistent with our subjective analyses. In other words, two statements that were apparently different to the investigator were not categorized as similar by the software. Also, two statements that were categorized as being the same by the investigator were not categorized as being different by the software. The software is also useful as a search machine. The user can enter a key word or phrase and the software will gather all responses including the word or phrase.

SPSS text analysis was used to determine vocabulary commonly associated with the similarities that we categorized as causal (Table 3). The data are interpreted to indicate that students' causal analogies can be recognized by use of relatively few terms. For example, most students who wrote causal similarities when retrieving and mapping analogs about subduction used the term density. Most students who described causal similarities about photosynthesis

used the term energy. If SPSS text analysis helps us recognize a few terms or phrases that are consistently associated with causal or non-causal similarities, we will emphasize those terms and phrases in lectures and inclass activities.

	Condensation	Subduction	Rock Cycle	Photosynthesis	Degassing	Carbon cycle
Energy	4	2	8	54	1	4
Heat	4	4	3	4	8	2
Bonds	4					2
Temperature	18		5		21	1
Weathering			17			3
Density		22				
State change	7					19
Dissolve					3	
Gravity		1				
Pressure		2	2			2

TABLE 3. Words used by students when writing scientific similarities between targets, upper row and analogs that students chose. For example, 4 students mentioned energy when describing similarities between condensation and their analog, 2 when describing subduction, 8 when describing the rock cycle, etc.

5. PROPOSED WORK

The proposed project will: 1) create of a series of analogical reasoning exercises; 2) develop formative and summative assessments of analogical reasoning; and 3) determine of the extent to which students increase their ability to map, evaluate and retrieve analogies in relation to global climate change. Our focus on global climate change is a natural consequence of the fact that experts, when addressing both other experts and novices, rely on analogies to explain and make predictions about global climate change.

5a. Instructional Activities

We will utilize matched instructional activities in two sections of the same general education global change course, and activities will be infused across the semester for both sections. The PI (Sibley) will teach both sections to reduce the impact of instructor effects. Historically, sections of Global Change for non-majors enroll approximately 200 students. Because this is a general education course, the diversity of the class is approximately the same as that of the university as a whole.

Both the experimental and control sections will encounter analogies throughout the semester. It would be impossible to teach the control group without using analogies; in addition, Sibley's dedication to analogy would likely ensure that a non-analogy control would be at a false disadvantage. However, only the experimental group will explicitly practice the five cognitive processes involved in understanding and generating analogies. The control section will mimic the experimental group but instead of analyzing and building analogies, students in the control group will analyze and build explanations of the same phenomena. Students in the two sections will use identical learning resources, will receive identical instruction outside of the experimental differences, will receive equivalent amounts of lecture, discussion, and other instructional formats, and will have equal access to the instructor outside of class.

Experimental instructional interventions will be designed to help students accomplish the five analogical reasoning tasks listed below (table 4). Atmospheric convection as an analog for

thermohaline circulation in the oceans is a good example.

1. Mapping- Students will be given atmospheric circulation as an analog for thermohaline circulation in the oceans. The key causal similarity is density driven convection. There are many important differences. For example, students should note that solar radiation heats the lower atmosphere but the upper surface of the oceans. Students should recognize that differences in atmospheric density are due to temperature while, in the oceans, salinity is also important.
2. Evaluation- Students should recognize that inferences about thermohaline circulation require consideration of both salinity and temperature. They should also be able to infer that mechanical mixing of waters is necessary to prevent stratification of the oceans.
3. Abstraction- Students should be able to recognize that convection in the atmosphere, oceans and mantle are fundamental processes that move heat.
4. Re-representation- Analysis of students' responses to pre- and posttest questions about similarities and differences between atmospheric and oceanic circulation should demonstrate an ability to move from processes driven by specific properties such as temperature and salinity to a more general understanding that these are density driven processes.
5. Retrieval – Students may be able to use their abstract understanding of convection in the atmosphere and oceans to describe everyday examples such as temperature inversions.

Example Activity	Task Experimental Group	Task Control group
Reading in text: Read the USGS website on the hydrologic cycle.	What analogies are used? Mapping: What are the similarities and Differences between the analogs and targets? Abstraction and re-representation: Based on these analogies, explain the concept of residence time.	List the reservoirs and processes that move and change matter.
Inclass exercise: Lecturer demonstrates degassing of cold and warm soda pop.	Evaluation: Based on the soda pop analog, what inferences might one draw about degassing of the oceans?	Explain how global temperature may affect the amount of CO ₂ dissolved in the oceans.
Online homework on condensation	Retrieval, mapping and evaluation: Retrieve, map and evaluate your own analog for condensation.	Explain the process of condensation.
Reading authentic literature (e.g. Alley 2004, on Rapid Climate Change)	Mapping and evaluation: What analogies does the author use? Describe similarities and differences between the analog and target. Based on the behavior of the analog, what can one infer about the target?	Explain why scientists fear the rate of climate change could change dramatically.
Reading authentic literature (e.g. Arrigo 2007)	What warrants and backing support the claim that there is a direct relationship between the concentration of CO ₂ in the atmosphere and the amount of CO ₂ sequestered by marine plankton?	Same question as experimental group.

TABLE 4. Examples of six types of activities that will be done with the two parallel sections.

Students will practice with a variety of materials during in class group exercises and online homework assignments (Table 4). Students will work in groups because these exercises require knowledge association and integration. When one person is stuck, a suggestion from another may move the group forward. Along with a free online global change text written by the PI, students will

read online resources such as the USGS website on the hydrologic cycle, and read authentic literature from sources such as *Scientific American*, news features articles in *Nature* and news of the week articles in *Science*. Students will be asked to recognize, map and evaluate analogies presented in some of these readings. In some cases, we will present analogies designed to test whether students are able to preserve a structurally consistent mapping: for example, an analogy in which the same element occurs in both situations, but in a different structural role; in such cases, novices may incorrectly map the analogy, making a false correspondence between the matching elements (Gentner and Toupin 1986). If this happens, we will show the student why this is wrong and explain the correct mapping. Students will be asked to describe the grounds, claims, warrants and/or backings described in the readings. For each reading assignment, we will develop rubrics that will guide students in practicing the specific step or steps. For example, a rubric for mapping may ask whether shared characteristics are physical or relational and if relational, whether or not they are causal. Students will write responses using LON CAPA (any other system that allows instructors to download student responses into a spreadsheet will work equally well). Students' responses will be downloaded into SPSS text analysis software to permit rapid analysis of common terms and phrases used in the responses. SPSS Text Analysis will allow us to quickly categorize student responses and address those responses in the next class or re-design questions when student responses seem inappropriate. For example, we know from our previous work that a common student generated analog for subduction is collision between a truck and a car with a truck representing continental crust and the car representing oceanic crust. This opens the way to a discussion about features versus causes and causes versus effects.

5b. Assessment

Formative and summative assessment of student learning will be based on comparing students' work in the experimental and control groups. Questions 1- 5 below will be addressed with both formative and summative assessment instruments. Question 6 will be summative assessments only. Example assessment instruments are outlined in Table 4. Assessment instruments and rubrics for questions 1 - 5 will be designed by Libarkin, Sibley and a postdoctoral fellow working under the direction co-PI Gentner. This collaborative approach is critical to developing instruments that are both consistent with Gentner's previous experiments on the cognitive basis for analogical reasoning and scientifically useful and appropriate content for the class. Question 6 will help us decide whether or not some groups of students are better at analogical reasoning than others.

1) *Do students recognize analogies?* Inclass exercises and online homework will provide students the opportunity to practice recognizing analogies. For example, the first analogy exercise will be weaver ant video that presents 13 analogs in 55 seconds. A 5-minute video on buoyancy contains six analogies, but they are less obvious. Students will also be challenged to recognize analogies in readings such as the USGS website on the water cycle. Late in the semester, students will read about rapid climate change (Alley 2004). This article includes a very obvious tipping canoe analog but also a less obvious temperature balance analog.

2) *Do students understand the difference between causal relationships and other types of relationships?* Inclass exercises and online homework will provide students ample opportunity to map analogs on targets. An important part of *mapping and evaluation* involves recognizing types of similarity between analog and target. For example, students will be asked to map sea ice as an analog for plate tectonics. The analogy, presented in a How Stuff Works video (howstuffworks.com), states that "When flows jam together, they push up chunks of ice known as pressure ridges. This is plate tectonics on the water." This analog presents physical similarity but is a not good relational analog for uplift at convergent plate boundaries and, in fact, may contribute the common misconception that mountains are pushed up in a manner similar to a carpet bunching up as it is pushed over a rigid floor (Sibley 2005). This analog fails to map the important principle of buoyancy.

Equally important, we will ask whether students can distinguish bad analogies from good ones. We expect this ability to increase over the quarter.

3) *Are specific components of the 5 aspects of analogical reasoning (Table 4) particularly challenging and therefore require more practice?* We expect students to have most difficulty with *retrieval* because retrieval requires considerable content knowledge. Based on cognitive scientists' findings that people recognize similarities more readily than differences (Markman and Gentner, 1993; Johnson- Laird 2006), we also suspect that students will list more relational similarities than differences between source and target. In the sea ice analog, one hopes students would recognize that slab pull is an important cause of tectonic plate motion but not an important cause of ice motion.

4) *Is there a difference in content knowledge between experimental group and the control group?* Analogical reasoning requires more than rote memorization. The acts of *re-representation and abstraction* are forms of learning. Therefore, we expect that students who practice analogical reasoning will also understand content better than those in the control group. One measure of students' content knowledge is their ability to complete box and arrow diagrams that describe movement and change of matter through natural cycles (Sibley et al 2007). Students in both sections will practice many box and arrow diagram exercises for the water cycle, Ca-cycle and C-cycle.

We will compare scores on all diagrams used as test items in two sections as one measure of content. Content knowledge will also be tested with multiple choice test items. We will use reliable and valid questions from the Chemistry Concept Inventory (<http://jchemed.chem.wisc.edu>) and the Geoscience Concept inventory (<https://www.msu.edu/~libarkin/gci.html>). Additional items will be developed and submitted to the Geoscience Concept Inventory for peer review. These items will be submitted during summer 2009, allowing time for validation prior to this study.

5). *Is there a difference in students' ability to articulate warrants and backings used to support claims about global change?* Homework exercises and test items will involve reading authentic literature and identifying grounds, claims, warrants and backing. In most cases, claims will be identified for the students. They will be asked to identify the warrants and backings cited in the article. We will compare scores between the experimental and control group.

6) *Do student scores on the analogy test questions correlate with race, ethnicity, and gender, GPA and ACT scores?* Analogy-based exercises are very different from most exercises students encounter in science classes. Therefore, we are particularly interested in how different groups fare. Even though class sizes will be relatively large (~200) university records available to all instructors demonstrate that classes may have significantly different incoming GPAs, as well as different demographics. We will use factor analysis to allow us to account for differences in performance on items that may be related to race, ethnicity, gender, GPA and ACT. In addition, we will determine whether or not some groups, as defined by these five factors, do better in the experimental or control group.

5c. Validity and Reliability

All instruments used to test conceptual understanding will be submitted to Geological Concept Inventory for peer review and must, therefore, meet standards for validity and reliability. Many of our assessment instruments will rely on students' written responses. We have carefully considered study validity, the extent to which the proposed qualitative data collection will represent actual models of college students as well as reliability, the reproducibility of our work, in designing this project. In particular, we have adopted the approach put forth by Lincoln and Guba (1985; further clarification in Trochim 2004), wherein qualitative analogs to the quantitative measures of internal and external validity, reliability, and objectivity are advocated as means for ensuring quality in qualitative research.

Credibility. Credibility correlates with internal validity, and addresses the issue of agreement between researcher findings and participant perspectives. During the second year of this

project, we will present our findings to groups of students similar to those evaluated during year one, and determine if agreement exists between findings and student opinion.

Transferability. The utility of research for the broader science education community hinges on our ability to demonstrate significance in other contexts. All study variables need to be defined so that future researchers can make reasonable assumptions about applicability to other settings.

Dependability. Dependability correlates to study reliability, and as such answers the question: Is the study repeatable, are findings stable over time, and do different measures of the same trait yield similar results? Similarly, interview protocols will be adjusted in response to initial pilot interviews. In addition, a dependable data analysis is one that multiple researchers can duplicate. Inter-rater reliability is one approach that can be used to gauge agreement between researchers.

Confirmability. The qualitative nature of the data collected in this study necessitates careful consideration of confirmability, primarily through response to the questions: Are study findings independent of the researcher's own personal biases, and therefore objective? Would another researcher reviewing the interpretation process come to the same conclusion? The inclusion of an evaluation board on this project will help ensure that bias is limited.

5d. Quasi-Experimental Design

Students enrolled in both experimental and control sections will be exposed to the instructional activities that done throughout the semester in two sections of the same course general education Global Change course. There will be multiple instances of each of the type of instructional activities. The PI (Sibley) will teach both sections. We recognize that this design can induce a bias against traditional instruction when a reform-minded instructor attempts to teach both a reform-oriented and a non-reform section. In this case, both sections will be taught using identical approaches, many of which have evolved in response to growing understanding of how people learn on Sibley's part. The only difference between the two sections will be the incorporation of specific analogical reasoning instruction for in the experimental section; the control section will focus on analyzing and building explanations of the same phenomena. Students in the two sections will be exposed to the same instruction and will have access to the same learning resources.

Students in the experimental group will map and evaluate analogies throughout the Global Change course. We will begin with the water cycle because it is relatively familiar to our students and the deals with processes that affect a single molecule. Conceptual models of processes of movement and change in the water cycle can serve as analogs for the less familiar and more complicated calcium and carbon cycles. For example, freezing of water can be an analog for precipitation of salts from solution. Evaluating this analogy helps students recognize similarities (both are exothermic) and differences (chemical change versus phase change). By the end of the course, we expect students to generate sophisticated analogies that allow them to explain causes of movement and change occur in the carbon cycle and to use these analogies to predict future global change. In this way, analogy building becomes a mechanism for developing and testing models.

6. WORK PLAN

Table 5. Project timetable.

YEAR 1	YEAR 2
<i>Spring 2010</i> 1. Design exercises and questions– many of these already exist but must be reviewed by Gentner's group. 1a. Develop scoring rubrics with research team <i>Fall 2010</i> 1. Teach 2 sections (experimental and control) Global Change class 2. Administer and analyze formative assessments. 3. Administer summative assessment instruments.	<i>Spring 2011</i> 1. Analyze formative and summative assessment data from Fall 2010 2. Interview students from Fall 2010 3. Redesign assessment questions and rubrics based on data from Fall 2010 <i>Fall 2011</i> 1. Repeat Fall 2010 scenario <i>Spring 2012</i> 1. Analyze formative and summative assessment data from Fall 2011 2. Submit publications.

7. EVALUATION

Evaluation, both formative and summative will be included throughout the study (Table 6).

		Questions asked	Approaches to evaluate question
Formative Evaluation	Implement-ation	Were instruments prepared according to timelines listed in table 5.	PI will provide evaluator with inclass exercises, homework's, rubrics etc.,
		Did investigators use collect multiple types of assessment data?	Evaluator will examine the formative and summative assessment instruments used and types of feedback provided to students.
		Was the student population selected for interviews diverse (gender, race, class level, abilities)?	Evaluator will check the demographic data gathered with interviews.
		Are student interviews conducted appropriately?	Evaluator will review taps and transcripts.
		Do activities and strategies implemented match those described in the plan?	Evaluator will compare assignments and assessment instruments and rubrics with table 2.
	Progress	Are data from both semesters integrated into a single, coherent data base	Evaluator will review the data base and entries from each semesters' data and interviews.
		Were initial results used to inform research in subsequent semesters?	Evaluator will review how the preliminary data were used to inform investigators work subsequent Fall 2011.
Summative Evaluation		Are all results analyzed and integrated appropriately?	Evaluator will review all data and data analyses.
		Are results disseminated locally?	Evaluator will review evidence that there is a viable plan to distribute instructional materials and assessment instruments in more MSU classes.
		Are the results disseminated nationally and internationally?	Evaluator will review dissemination on web, abstracts submitted for national and international meetings, articles submitted for publication.

Table 6. Project evaluation plan

The evaluation will be done by MSU's Center for Research in College Science Teaching and Learning (CRCSTL) Research Evaluation Board. The Board provides formative and summative evaluation for science education research projects. The Board is composed of faculty and administrators from the colleges of Natural Science and Education with expertise in science content, educational theory, qualitative and quantitative research. Methodologies, regulations and protocols for working with human subjects, and institutional priorities, opportunities and constraints that affect research design, implementation and dissemination.

7. DISSEMINATION

Presentations will be made at both geology and science education professional meetings, such as Geological Society of America (GSA) and National Association for Research in Science Teaching (NARST). Publication will occur in journals targeted towards both groups, such as *Journal of Geoscience Education*, *International Journal of Science Education*, and *Journal of Science Education*. We will submit materials for dissemination via FLAG and DLESE websites and findings relevant to the Geoscience Concept Inventory will be posted on the GCI webpage (to be hosted through MSU under a different project) prior to the operation of the fully functional web center. MSU has also agreed to host the GCI web center beyond the term of the project (NSF-DUE-0717790)

Part of the dissemination of this work will follow from its relationship to other NSF supported projects at MSU.

- Collaborative Research: Community Development of an Expanded Geoscience Concept Inventory: A Web center for Question Generation, Validation and Online Testing. Julie Libarkin, PI. NSF 0717790. Libarkin is an expert in methodological and psychometric approaches to concept inventory development. We will publish analogical reasoning exercises and data on student responses on the GCI website.
- Analysis of Student's Written Responses. Mark Urban-Lurain – PI (I). We will be exploring the possibility of using SPSS Text Analysis software to speed up the assessment of student analogies to discover patterns and connections between terms used by students. This tool may be very powerfully used in a just-in-time teaching mode wherein students would build analogies the night before class and discuss them during class.
- This project stems, in part, from Sibley's work on (NSF #0243126) developing clusters of questions designed to assess students' ability to engage in principled reasoning about natural systems. Through that work, we have developed clearer standards for the results of students' reasoning but we have not been explicit about the cognitive processes that lead to those results. The project proposed here will help us understand those cognitive processes.

9. PERSONNEL AND RESPONSIBILITIES

Note: To ensure good co-ordination between the MSU and Northwestern groups, we will meet via videoconference every two weeks and in person 4 times per year.

Dedre Gentner Professor in the Department of Psychology and the School of Education and Social Policy and Director of the Cognitive Science program at Northwestern University. Dr. Gentner and a postdoctoral fellow working under her direction, will review and critique all analogy exercises, assessment items and rubrics to assure they provide theoretically sound measures of analogical reasoning.

Julie Libarkin is an Assistant Professor jointly appointed in the Department of Geological Sciences and Division of Science and Mathematics Education at Michigan State University, with affiliation in the Cognitive Sciences Program. Dr. Libarkin will work with Dr. Sibley to develop rubrics for scoring students' analogies and establish the reliability and validity of scoring students' written responses. She will also oversee student interviews.

Duncan Sibley Professor of Geological Sciences and Director of the Center for Research on

College Science Teaching and Learning at Michigan State University will be project coordinator and will teach the experimental and control sections. He will oversee a graduate student who will assist him in developing rubrics and scoring. The graduate student will also collect data using the SPSS Text Analysis software.

Mark Urban-Lurain is Director of Instructional Technology Research and Development. He will oversee use of SPSS Text analysis software and design protocols for data analysis, including multivariate analysis of demographic data.

Personnel to be hired.

Postdoctoral fellow: We will hire a full-time time postdoctoral fellow at Northwestern University. The role of the post-doctoral fellow will be to evaluate develop rubrics, collect and score student work, and analyze transcripts and data from exercises.

Graduate Assistant

Evaluator: We will hire a College of Education Graduate student who has completed at least one graduate level course in evaluation to work with the CRCSTL evaluation board.

10. Post-Doctoral Training and Mentorship at Northwestern University.

The postdoc working on this project will work with Dr. Gentner on analysis of analogies designed to teach global warming and related topics; development of instructional materials and assessment tools; and analyses of data collected from the target classes. The postdoctoral fellow designated to work on this project with the Center for Spatial Intelligence and Learning (SILC)—a multi-university NSF Science of Learning Center. SILC has an established program for mentoring postdocs that is reflective of postdoc needs and expectations and that is aimed at inculcating strong interdisciplinary knowledge and research skills. SILC mentoring includes: (1) a weekly lab meeting in which students and postdocs present and critique each other's work; (2) a bi-weekly Spatial Cognition group meeting, bringing together researchers from Education, Psychology, Geoscience, and Computer Science to discuss papers and plan research; (3) weekly meetings with faculty advisors to discuss and plan research; (4) yearly meetings in which the students and postdocs of all five NSF SLCs come together and present research (faculty do not attend); this allows postdocs and grad students a chance to discuss and critique work on their own, and most importantly it fosters a set of collegial ties across institutions and across disciplines; (5) the requirement for all postdocs and grad students to pass the Institution Review Board human subjects protection training (<http://www.research.northwestern.edu/oprs/irb/education/>) (6) support and encouragement to write up and publish research in top journals, and to present research at national conferences.

11. Results of Prior NSF Support

Sibley: Prior work is described in the Dissemination section.

DUE -0243126: Diagnostic Question clusters: Development and testing in introductory geology and biology. \$491,606. 9/15/03-8/31/08. We developed clusters of questions designed to assess students' ability to engage in principled reasoning about cellular respiration, photosynthesis, and genetics (Wilson, et al. 2006a, Parker et al. 2007) as well as defining frameworks for reasoning about these topics. For the geological part of this project we have developed box and arrow diagrams (Sibley et al. 2007) to assess students' ability to engage in principled reasoning about the water, rock and carbon cycles.

DUE #0736952- see Urban-Lurain below.

Gentner Prior work is described in the Dissemination section. Gentner has two prior and one current NSF grant relevant to this work:

REC-0337360: ROLE: Understanding and Fostering Spatial Competence, \$628,100, 12/2003 – 11/2007 (Multi-University grant: University of Chicago – lead institution, Northwestern University, and Temple University). The goal was to understand the growth of spatial intelligence and to establish methods for maximizing the development of spatial skills. Using a cognitive science approach researchers investigated the mechanisms that are involved in learning and using spatial information. Methods included psychological experimentation, computational and statistical modeling, and classroom-based training. We examined the enhancement of spatial skill through comparison-based learning and using gesture to trace representational change. Additionally, researchers examined the developing use of spatial tools, such as graphs and measurement systems, to support quantitative learning.

SBE-0541957: SLC: Spatial Intelligence and Learning Center, Northwestern award to date: \$2,494,366, 09/2006 – 08/2011 (Multi-University grant: Temple University – lead institution, Northwestern University, University of Chicago, and University of Pennsylvania). The purpose of the Spatial Intelligence and Learning Center (SILC) is to understand human spatial cognition, with an emphasis on the idea that spatial knowledge and skills can be improved, and to apply the resulting knowledge to foster spatial learning, especially in STEM disciplines. The Analogy workgroup, headed by Dr. Gentner, has shown that comparison promotes spatial learning at every stage of human learning, from very young children to advanced students in STEM disciplines. Publications: Gentner et al. (in press), Christie and Gentner (2007) Day and Gentner (2007).

Libarkin: Prior work is described in the Dissemination section. Libarkin has two prior NSF grants that are relevant to this work: DUE-0127765: *Conceptual Understanding of Three Dimensions of Earth Processes in General Education and Introductory Courses: Test Development and Validation*; \$498,984; 10/01/01-9/30/05: 5000 students from over 40 institutions were tested during initial development of the Geoscience Concept Inventory (GCI), and over 100 faculty and researchers nationwide are now using the GCI. The GCI consists of a bank of 69 validated questions, is currently being expanded to 300-500 questions under a new NSF grant (DUE-0717790) and is the only nationally used concept inventory in the geosciences. The GCI was developed utilizing scale development theory, grounded theory, and item response theory. Dissemination of results includes more than thirty presentations and six peer-reviewed publications.

DUE-0717790: *Collaborative Research: Community Development of an Expanded Geoscience Concept Inventory: A WebCenter for Question Generation, Validation and Online Testing*; \$331,008; 09/01/07-08/31/10. This project builds on DUE-0127765, and will develop an online mechanism for development of new questions and assessment of students using the GCI. The community of geoscientists is being invited to become authors and reviewers of existing and new GCI questions. The GCI WebCenter development is near completion, with expected launch in summer 2009.

Urban-Lurain: DUE #0736952. *Analyzing Constructed Responses: Using Linguistic Software to Understand Students' Conceptions in Science*; \$150,000; 8/1/08 – 7/31/10. We are exploring the use of computerized lexical analysis of students' writing in large enrollment undergraduate biology and geology courses. We have created libraries that categorize student responses with > 90% accuracy. These categories can be used as independent variables in statistical classification techniques to predict expert ratings of student responses with accuracy approaching inter-rater reliability among expert raters (Interclass Correlations between the software and two experts = .84; between two experts = .94). These techniques also provide insight into students' use of analogical thinking, a fundamental part of scientific modeling (Haudek et al., 2009; Moscarella et al., 2008; Urban-Lurain et al., 2009).

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- Moscarella, R. A., Urban-Lurain, M., Merritt, B., Long, T., Richmond, G., Merrill, J., et al. (2008, March 30 - April 2). Understanding undergraduate students' conceptions in science: Using lexical analysis software to analyze students' constructed responses in biology. Paper presented at the NARST 2008 Annual International Conference, Baltimore, MD.
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- Raia, F., 2008, Causality in complex dynamic systems: a challenge in earth systems science education. *Journal of Geoscience Education*, 56. 81-94.
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Safayeni, F., Derbentseva, N., and Cañas, A. J., 2005. A theoretical note on concepts and the need for cyclic concept maps. *Journal of Research in Science Teaching* 42, 741-766.

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Sibley, D.F., Anderson, C.W., Heidemann, M., Merrill, J. E., Parker, J.M., Szymanski, D.W., 2007, Box diagrams to assess students' systems thinking about the rock, water and carbon cycles.: *Journal Geoscience Education*, 55, 138-146

Sterman, J. D., 2008, Reisk communication on climate; mental models and mass balance. *Science*, 322, 532-533.

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Trochim, W.M., 2004, *The Research Methods Knowledge Base*, 2nd Edition: Atomic Dog Publishing: Cincinnati, 363p.

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Urban-Lurain, M., Moscarella, R. A., Haudek, K. C., Giese, E., Sibley, D. F., & Merrill, J. E. (2009, October 18-21). Beyond multiple choice exams: Using computerized lexical analysis to understand students' conceptual reasoning in STEM disciplines Paper presented at the *Frontiers in Education*, San Antonio, TX.

Walsh, B., 2008, What the public doesn't get about climate change. *Time Magazine*, Oct. 28, 2008.

Duncan F. Sibley

Director, Center for Research on College Science Teaching and Learning
114 Natural Science, Michigan State University, East Lansing, MI 48824
sibley@msu.edu

(a) Professional Preparation

Lafayette College	Geology	B.A.	1968
Rutgers University - New Brunswick	Geology	M.S.	1971
Univ. Oklahoma	Geology	Ph.D.	1974

(b) Appointments

Director, Center for Research on College Science Teaching and Learning, 2007
Associate Dean for Science for College and Mathematics Education, 2007
Director, Center for Integrative Studies, General Science, 1999-2006
Professor, Dept. Geological Science, 1974-present

(c) Publications

Recent publications relevant to proposal

Sibley, D.F., 2005, Visual abilities and misconceptions about plate tectonics: *Journal Geoscience Education*, 53, 471-477.

Wilson, C. D. Anderson, C.W., Heidemann, M., Merrill, J.E., Merritt, B.W., Richmond, G., Sibley, D.F., and Parker, J.M., 2006, Assessing students' ability to trace matter in dynamic systems in cell biology. *CBE Life Science Education*. 323-331.

Sibley, D.F., Anderson, C.W., Heidemann, M., Merrill, J. E., Parker, J.M., Szymanski, D.W., 2007, Box diagrams to assess students' systems thinking about the rock, water and carbon cycles,: *Journal Geoscience Education*, 55, 138-146

Parker, J., Anderson, C., Merrill, J. Heidemann, M., Long, T., Merrill, J., Merritt, B., Richmond, G., Sibley, D., Urban-Lurain, M., and Wilson, C. Where has all the carbon gone?: A thought paper on frameworks for assessing biology understanding. *Conceptual Assessment in Biology Conference Proceedings – March 3 – 4, 2007. Boulder, CO.*

Urban-Lurain, M., Moscarella, R. A., Haudek, K. C., Giese, E., Sibley, D. F., & Merrill, J. E. (2009, October 18-21). Beyond multiple choice exams: Using computerized lexical analysis to understand students' conceptual reasoning in STEM disciplines Paper presented at the *Frontiers in Education*, San Antonio, TX.

Other Recent Publications

Makowitz, A. and Sibley, D.F., 2001, Crystal growth mechanism for quartz overgrowths: *Journal of Sedimentary Research* 71, 809-816.

Sibley, D.F., 2003, Dolomite Textures, in G. Middleton (ed) *Encyclopedia of Sediments and sedimentary Rocks*, Kumar Press, 231-234.

Riffell, S. K. and D. F. Sibley. 2004. Can hybrid course formats increase attendance in undergraduate environmental science courses? *Journal of Natural Resources and Life Sciences Education*, 33, 16-20.

Riffell, S. K. and D. F. Sibley. 2005, Using we-based instruction to improve large undergraduate biology courses: an evaluation of hybrid course format. *Computers & Education*, 44, 217-235.

Kaczmarek, S. E. and Sibley, D.F., 2007, A comparison of nanometer scale growth feature and dissolution features on natural and synthetic dolomite crystals: implications for the origin of dolomite. *Journal Sedimentary Research*, 77, 424-432.

(d) Synergistic Activities

1. As Director of Center for Integrative Studies- General Science at Michigan State University I worked with faculty from 10 different departments across two colleges to develop curricula and assess student learning outcomes in general education science courses.
2. As director of a new Center for Research in College Science Teaching and Learning, I will help bring together faculty, post doctoral researchers and graduate students from the colleges of Natural Science, Education, and Agricultural and Natural Resources to work in interdisciplinary team research on science education. The center has resources from the university to seed some of this research.
3. Co PI on Diagnostic Question Clusters, Development and Testing in Introductory (NSF ASA grant).
4. As acting Associate Dean for Science and Math Education in the College of Natural Science I work to support and improve all aspects of teaching and learning within our college and collaborate with others around the university concerned with issues of teaching and learning.

(d) Collaborators and Other Affiliations

Collaborators and Co-Editors

Charles Anderson, Michigan State University
Merle Heidemann, Michigan State University
John Merrill, Michigan State University
Joyce Parker, Michigan State University
Mark Reckase, Michigan State University
Donna Sundre, James Madison University
Davis Szymanski, GSA Congressional Fellow, Washington, DC
Christopher Wilson, BSCS, Colorado Springs, CO

Graduate Advisors and Postdoctoral Sponsors

Raymond Murray (emeritus)
Harvey Blatt (emeritus)

Thesis Advisor and Postgraduate-Scholar Sponsor

Steve Kaczmarek, ExxonMobil
Total Graduate Students- 17 MSc, 6 PhD

Julie C. Libarkin

Department of Geological Sciences & Division of Science and Mathematics Education
206 Natural Science Bldg., Michigan State University, East Lansing, MI 48824
libarkin@msu.edu

Professional Preparation

College of William & Mary	Geology/Physics	B.S.	1994
University of Arizona	Geosciences	Ph.D.	1999
University of Arizona	NSF Post-doctoral Fellow in Science, Mathematics, Engineering, and Technology Education (PFSMETE) Fellow	Post-doctoral	1999-2000
Harvard-Smithsonian Center for Astrophysics	PFSMETE Fellow	Post-doctoral	2000-2002

Appointments

08/2006-present	Assistant Professor, Department of Geological Science & Division of Science and Mathematics Education, Michigan State University
08/2003-08/2006	Assistant Professor, Department of Geological Sciences, Ohio University.
08/2002-08/2003	Research Associate, Science Education Department, Harvard-Smithsonian Center for Astrophysics
01/2000-06/2000	Adjunct Lecturer, Department of Geosciences, University of Arizona

Selected Related Publications

- Libarkin, J.C.**, Kurdziel, J.P., and Anderson, S.W., 2007, College student conceptions of geological time and the disconnect between ordering and scale: *Jour. of Geoscience Education*, 55, 413-422.
- Libarkin, J.C.**, and Anderson, S.W., 2006, The Geoscience Concept Inventory: Application of Rasch Analysis to Concept Inventory Development in Higher Education: in *Applications of Rasch Measurement in Science Education*, ed. X. Liu and W. Boone: JAM Publishers, 45-73.
- Libarkin, J.C.**, and Kurdziel, J.P., 2006, Ontology and the teaching of earth system science: *Jour. of Geoscience Education*, 54, 408-413.
- Dahl, J., Anderson, S.W., and **Libarkin, J.C.**, 2005, Digging into earth science: alternative conceptions held by K-12 teachers: *Jour. of Science Education*, 6 (2), 65-68.
- Libarkin, J.C.**, and Anderson, S.W., 2005, Assessment of learning in entry-level geosciences courses: Results from the Geoscience Concept Inventory: *Jour. of Geoscience Education*, 53, 394-401.

Selected Other Publications

- Clark, S.K., Sibley, D., **Libarkin, J.C.**, and Heidemann, M., A novel method to teaching and understanding transformations of matter in dynamic Earth systems: *Jour. of Geoscience Education*, *in review*.
- Garzione, C.N., Hoke, G.D., Libarkin, J.C., Withers, S., MacFadden, B., Eiler, J., Mulch, A., Ghosh, P., 2008, The Rise of the Andes: Pulsed Surface Uplift in Orogenic Plateaus: *Science*, 320, 1304-1307.
- Coblentz, D., **Libarkin, J.C.**, Sussman, A., and Chase, C.G., 2007, Paleolithospheric structure revealed by continental geoid anomalies: *Tectonophysics*, 443, 106-120.
- Farley, K.A., **Libarkin, J.C.**, Mukhopadhyay, S., and Amidon, W., 2006, Cosmogenic ³He in Apatite, Titanite, and Zircon: *Earth and Planetary Science Letters*, 248, 436-446.

Libarkin, J.C., Anderson, S., Dahl, J., Beilfuss, M., Boone, W., and Kurdziel, J., 2005, College students' ideas about geologic time, Earth's interior, and Earth's crust: *Jour. of Geoscience Education*, 53 (1), 17-26.

Synergistic Activities

1. Organizer of a geocognition and geoscience education research interest group at the Geological Society of America national meetings (2006, 2007, 2008). This led to the establishment of an email list-serve, with co-host Heather Petcovic. List-serve is also co-hosted by Eric Pyle. The GEOED-RESEARCH list-serve runs through Michigan State University's list-serve service, and currently has over 150 members.
2. Developed and implemented a research program in the Geocognition Research Laboratory (GRL) for the M.S. and Ph.D. in Geological Sciences at Michigan State University (MSU). Students complete coursework in Geological Sciences while conducting disciplinary research in Geocognition, and have the opportunity to participate in the Cognitive Sciences specialization already in existence at MSU. Two Ph.D. students, a visiting scholar, two undergraduates and a postdoctoral fellow have worked in the GRL since 2007.
3. Co-Editor for Production, *Journal of Geoscience Education* (2009-2011) and Shea Award Recipient (2007), National Association of Geoscience Teachers; co-author of a JGE review series on Research in Science Education (recipient of the 2007 Shea Award in partial honor of this series). Efforts in Co-Editorship include modernization of review criteria and collaboration with international scholars.
4. Content expert and interviewer for the Essential Science Series for elementary teachers created by the Science Media Group at the Harvard-Smithsonian Center for Astrophysics. Interviewed over 40 children and provided expertise in evaluating Earth Science content of the series. Continued collaboration with the Science Media Group on Habitable Earth series.
5. Principle Investigator on NSF-DUE grants for development and community involvement in the Geoscience Concept Inventory. Activities include analysis of student ideas about the Earth system and creation of a multiple-choice concept inventory (Geoscience Concept Inventory; GCI) that can be used as a valid and reliable assessment of changes in student conceptual understanding. Over 4000 students from 60 courses at 40 institutions nationwide have participated in this study, which resulted in six publications and over thirty presentations. 200+ faculty and researchers are now using the GCI. A second grant from DUE-CCLI for revision and expansion of the GCI was funded in Fall 2007.

Collaborators (in last 4 years). *Anila Asghar*, Johns Hopkins Univ.; *Steven Anderson*, Univ. of Northern Colorado; *David Coblenz*, Los Alamos National Labs; *Kenneth Farley*, California Institute of Technology; *Carmala Garziane*, Univ. of Rochester; *Zach Hambrick*, Michigan State Univ.; *Helen King*, Helen King Consultancy; *Josepha Kurdziel*, Univ. of Michigan; *Heather Petcovic*, Western Michigan Univ.; *Philip Sadler*, Harvard-Smithsonian Center for Astrophysics; *Matt Schneps*, Science Media Group, Harvard-Smithsonian Center for Astrophysics; *Alison Stokes*, Univ. of Plymouth; *Aviva Sussman*, Los Alamos National Labs.

Graduate and Post-doctoral Advisors. Robert F. Butler, Univ. of Arizona; Reed Mencke, Univ. of Arizona; Philip Sadler, Harvard-Smithsonian Center for Astrophysics

Thesis Advisor and Postgraduate-Scholar Sponsor. Ohio Univ.: *Timothy Sekula*, M.S.; *Marcus Wunderle*, M.S.; *Saunia Withers*, B.S. Michigan State Univ.: *Scott K. Clark*, postdoctoral fellow; *Juli A. Moore*, Ph.D. student; *Sheldon Turner*, Ph.D. student

Mark Urban-Lurain
Director of Instructional Technology Research & Development
Division of Science and Mathematics Education
111 N. Kedzie Labs, Michigan State University, East Lansing, MI 48824
urban@msu.edu

(a) Professional Preparation

Michigan State University	Television – Radio	B. A.	1972
Michigan State University	Multidisciplinary Social Science	M. A.	1981
Michigan State University	Educational Psychology	Ph.D.	2000

(b) Appointments

2002 – present	Director of Instructional Technology Research and Development, Division of Science and Mathematics Education, Michigan State University
1997 – 2002	Academic Specialist: Instructor, Department of Computer Science and Engineering, Michigan State University
1985 - 1997	Instructional Resources Coordinator, Computer Science Department, Michigan State University
1979 - 1985	Television Engineering Technician II, Instructional Public Television, Michigan State University
1976 - 1978	Graduate Programming Assistant, Computer Institute for Social Science Research, Michigan State University
1974 – 1979	Radio Production Technician, WKAR Radio, Michigan State University

(c) Publications

Related to project:

Urban-Lurain, M., Moscarella, R. A., Haudek, K. C., Giese, E., Sibley, D. F., & Merrill, J. E. (2009, October 18-21). *Beyond multiple choice exams: Using computerized lexical analysis to understand students' conceptual reasoning in STEM disciplines*. Paper presented at the Frontiers in Education, San Antonio, TX.

Haudek, K., Moscarella, R. A., Urban-Lurain, M., Merrill, J., Sweeder, R., & Richmond, G. (2009, April 17-21). *Using lexical analysis software to understand student knowledge transfer between chemistry and biology*. Paper presented at the National Association of Research in Science Teaching Annual Conference, Garden Grove, CA.

Moscarella, R. A., Urban-Lurain, M., Merritt, B., Long, T., Richmond, G., Merrill, J., et al. (2008, March 30-April 2). *Understanding undergraduate students' conceptions in science: Using lexical analysis software to analyze students' constructed responses in biology*. Paper presented at the NARST 2008 Annual International Conference, Baltimore, MD.

Richmond, G., Urban-Lurain, M., Parker, J., Merrill, J., & Merritt, B. (2008, March 30 - April 2). *Assessment-informed instructional design to support model-based reasoning in college-level biology*. Paper presented at the NARST 2008 Annual International Conference, Baltimore, MD.

Urban-Lurain, M. (2003). Fluency with information technology: The computer science perspective. In Y. Zhao (Ed.), *What should teachers know about technology: Perspectives and practices* (pp. 53-74). Greenwich, CT: Information Age Publishing.

Other:

Urban-Lurain, M., Briedis, D., Buch, N., Erlich, N., Sticklen, J., & Wolff, T. F. (2009, June 14-17). *Understanding factors contributing to retention in engineering: A structural equation modeling (SEM) approach*. Paper presented at the ASEE Conference and Exposition, Austin, TX.

Vergara, C. E., Urban-Lurain, M., Dresen, C., Coxen, T., MacFarlane, T., Frazier, K., et al. (2009, October 18-21). *Aligning computing education with engineering workforce computational needs: New curricular directions to improve computational thinking in engineering graduates*. Paper presented at the Frontiers in Education, San Antonio, TX.

Urban-Lurain, M., Albertelli, G., & Kortemeyer, G. (2005, October 19 - 22). *Using information technology to author, administer, and evaluate performance-based assessments*. Paper presented at the Frontiers in Education, Indianapolis, IN.

Urban-Lurain, M., Anderson, C. W., Parker, J., & Richmond, G. (2006, March 20-24). *Fluency with information technology in teacher education: Moving from novice towards expertise*. Paper presented at the Society for Information Technology & Teacher Education, Orlando, FL.

Urban-Lurain, M., & Sticklen, J. (2008, October 22-25). *Enhancing learning of low performing students in multi-section first year lecture/laboratory classes: Completion of a three year study*. Paper presented at the Frontiers in Education, Saratoga Springs, NY.

(d) Synergistic Activities

Steering Committee for Future Academic Scholars in Teaching (FAST): Scholarship of Teaching and Learning (SoTL) mentored teaching experiences for STEM graduate students.

Conceived, designed, implemented and directed an introductory computing course for non-CS majors serving 2000 students/semester. Consistent with the NRC *Fluency with Information Technology* recommendations, the course combines active, collaborative learning with mastery-model performance-based assessment to promote retention and enhance transfer.

Recipient of 2001 MSU Alumni Club of Mid-Michigan Quality in Undergraduate Education award and 1999 MSU College of Engineering Withrow Teaching Excellence award.

(e) Collaborators & Other Affiliations

Collaborators & Co-Editors: Albertelli, Guy, MSU; Amey, Marilyn, MSU; Anderson, Charles, MSU; Briedis, Daina, MSU; Buch, Neeraj, MSU; Eberhardt, Jan, MSU; Ebert-May, Diane, MSU; Hinds, Timothy, MSU; Jones, Matthew, UC Santa Barbara; Koehler, Matt, MSU; Kortemeyer, Gerd, MSU; Lundeborg, Mary, MSU; McFall, Ryan, Hope College; Merrill, John, MSU; Miller, Dennis, MSU; Mishra, Punya, MSU; Ofoli, Robert, MSU; Parker, Joyce, MSU; Patterson, Ronald, MSU; Richmond, Gail, MSU; Rollins, Scott, UCSC; Rosaen, Cheryl (MSU); Sibley, Duncan, MSU; Sticklen, Jon, MSU; Weinshank, Donald J. (emeritus), MSU; Zhang, BaoHui, Nanyang Technology University; Zhao, Yong, MSU.

Graduate Advisors: Byers, Joseph L. (emeritus), MSU; Weinshank, Donald J. (emeritus), MSU; Yelon, Stephen L. (emeritus), MSU; Zhao, Yong, MSU.

Graduate student thesis advisor: None

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Dedre Gentner, Northwestern University

May 21st, 2009

BIOGRAPHICAL SKETCH: DEDRE GENTNER

Professional Preparation

1962-1967	University of California, Berkeley	B.A., Physics
1967-1968	University of Chicago	Social Sciences
1970-1974	University of California, San Diego	Ph.D., Psychology

Appointments

2007-present	Alice Gabrielle Twight Professor of Psychology and Education, Northwestern University
1990-present	Professor of Psychology, Professor of Education; Director, Cognitive Science Program, Northwestern University
2006	Fellow, Rockefeller Institute, Bellagio, Italy
1999-2000	Fellow, Center for Advanced Study in the Behavioral Sciences, Stanford
1989-1990	Professor of Psychology, Univ. of Illinois at Urbana-Champaign.
1984-1989	Assoc. Prof. of Psychology, Univ. of IL at Urbana-Champaign.
1977-1982	Scientist, Bolt Beranek and Newman, Inc.
1974-1977	Assistant Professor of Psychology, University of Washington.
1968-1970	Teacher, Achimota Preparatory School, Achimota, Ghana.

Publications

- [1] Gentner, D., Levine, S., Dhillon, S., Poltermann, A. (in press). Using structural alignment to facilitate learning of spatial concepts in an informal setting. Paper to be presented at the 2nd International Analogy Conference. Sofia, Bulgaria.
- [2] Gentner, D., Loewenstein, J., & Hung, B. (2006). Comparison facilitates children's learning of names for parts. *Journal of Cognition and Development*, 7(2).
- [3] Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology* 95 (2), 393-408.
- [4] Gentner, D., Holyoak, K. J., & Kokinov, B. N. (Eds.). (2001). *The analogical mind: Perspectives from cognitive science*. Cambridge, MA: MIT Press.
- [5] Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist*, 52, 45-56.

5 Other Significant Publications

- [1] Gentner, D. & Loewenstein, J. (2002b). Relational language and relational thought. In J. Byrnes & E. Amsel (Eds.), *Language, Literacy, and Cognitive Development* (pp. 87-120). Mahwah, NJ: Erlbaum.
- [2] Namy, L. L. & Gentner, D. (2002). Making a silk purse out of two sow's ears: Young children's use of comparison in category learning. *Journal of Experimental Psychology: General*, 131, 5-15.
- [3] Rattermann, M. J., & Gentner, D. (1998b). More evidence for a relational shift in the development of analogy: Children's performance on a causal-mapping task. *Cognitive Development*, 13, 453-478.
- [4] Gentner, D., Rattermann, M. J., & Forbus, K. D. (1993). The roles of similarity in transfer: Separating retrieval from inferential soundness. *Cognitive Psychology*, 25, 524-575.
- [5] Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, 7, 155-170.

Synergistic Activities

- Development of analogical encoding techniques as a new method of instruction that multiplies the value of case-based training. Our research shows that techniques in which learners are encouraged to compare and align two analogous lead to better transfer, better retrieval of past relevant experiences, and better ability to notice relevant differences than learning on a case-by-case basis.
- We have implemented our analogical encoding learning in the teaching of negotiation strategies to business students. When advanced MBA students write out the commonalities and differences between two analogous negotiation cases, they perform twice as well in a subsequent negotiation

based on the strategy than they do if they study the two analogs separately.

- Selected honors & awards: Fellow of the Center for the Study of the Behavioral Sciences, Stanford, 1999-2000; member of the Inaugural Set of Fellows of the Cognitive Science Society.
- The two recently coedited books – The analogical mind (2001) and Language in mind (2003) – are having an impact on the field of cognition and learning.

Collaborators and Other Affiliations

Collaborators and Co-editors: Galen Bodenhausen, NWU; Brian Bowdle, Indiana University; Penelope Brown, Max Planck Institute; Mei-Hung Chiu, Taiwan Normal University; Ronald Ferguson, Georgia Tech; Michele Feist, Louisiana State University; Kenneth Forbus, NWU; Susan Goldin-Meadow, University of Chicago; Keith Holyoak, UCLA; Boicho Kokinov, New Bulgarian University; Sven Kuehne, NWU; Kenneth Kurtz, Binghamton University; Jeffrey Loewenstein, UT-Austin; Arthur Markman, UT-Austin; David Perrott, NWU; Laura Namy, Emory; Asli Osyurek, Koc University, Istanbul; Leigh Thompson, NWU; Michael Tomasello, Max Planck Institute; David Uttal, NWU; Phillip Wolff, Emory.

Graduate and Post-doctoral Advisors: Donald Norman, Northwestern University; David Rumelhart, Stanford University.

Thesis Advisor and Postgraduate-Scholar Sponsor (Total 22 Students Advised):

Current Ph.D Students: Jason Jameson, Stella Christie, Julie Colhoun, Linsey Smith, Anja Jamrozik

Current Postdoctoral students: Benjamin Jee,

Former Students: Samuel Day, Indiana University; Brian Bowdle, Indiana University; Sarah Brem, Arizona State University; Catherine Clement, Eastern Kentucky State University; Ron Ferguson, Georgia Tech; Michele Feist, Louisiana State University; Rob Goldstone, Indiana University; Mutsumi Imai, Keio University; Kenneth Kurtz, Binghamton University; Bjorn Levidow, Microsoft; Jeffrey Loewenstein, UT-Austin; Joyce Ma, Exploratorium; Arthur Markman, UT-Austin; Jose Medina, Vanderbilt; Mary Jo Rattermann, Swarthmore College; Phillip Wolff, Emory.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION Michigan State University				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Duncan Sibley				PROPOSAL NO.		DURATION (months)	
				Proposed		Granted	
AWARD NO.							
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	
				CAL	ACAD	SUMR	Funds granted by NSF (if different)
1. Duncan Sibley - PI				0.00	0.00	0.00	\$ 0
2. Julie C Libarkin - Co-PI				0.00	0.00	0.00	0
3. Mark Urban-Lurain - Co-PI				0.00	0.00	0.00	0
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00	0
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (1) GRADUATE STUDENTS							16,352
4. (1) UNDERGRADUATE STUDENTS							5,177
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							21,529
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							1,950
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							23,479
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							500
2. FOREIGN							0
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							500
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							7,698
TOTAL OTHER DIRECT COSTS							8,198
H. TOTAL DIRECT COSTS (A THROUGH G)							32,177
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
Modified Total Direct Cost (Rate: 52.0000, Base: 24479)							
TOTAL INDIRECT COSTS (F&A)							12,729
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							44,906
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 44,906 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Duncan Sibley				FOR NSF USE ONLY			
ORG. REP. NAME* Emily Flanner				INDIRECT COST RATE VERIFICATION			
		Date Checked		Date Of Rate Sheet		Initials - ORG	

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0941492

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION Michigan State University				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Duncan Sibley				PROPOSAL NO.	DURATION (months)		
				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
				CAL	ACAD	SUMR	
1. Duncan Sibley - PI				0.00	0.00	0.00	\$ 0
2. Julie C Libarkin - Co-PI				0.00	0.00	0.00	0
3. Mark Urban-Lurain - Co-PI				0.00	0.00	0.00	0
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00	0
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (1) GRADUATE STUDENTS							16,842
4. (1) UNDERGRADUATE STUDENTS							5,333
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							22,175
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							2,106
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							24,281
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							500
2. FOREIGN							0
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							500
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							1,500
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							8,237
TOTAL OTHER DIRECT COSTS							10,237
H. TOTAL DIRECT COSTS (A THROUGH G)							35,018
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) Modified Total Direct Cost (Rate: 52.0000, Base: 26781)							
TOTAL INDIRECT COSTS (F&A)							13,926
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							48,944
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 48,944 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Duncan Sibley				FOR NSF USE ONLY			
ORG. REP. NAME* Emily Flanner				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

2 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0941492

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION Michigan State University				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Duncan Sibley				PROPOSAL NO.		DURATION (months)	
				Proposed		Granted	
AWARD NO.							
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	
				CAL	ACAD	SUMR	Funds granted by NSF (if different)
1. Duncan Sibley - PI				0.00	0.00	0.00	\$ 0
2. Julie C Libarkin - Co-PI				0.00	0.00	0.00	0
3. Mark Urban-Lurain - Co-PI				0.00	0.00	0.00	0
4.							
5.							
6. () OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00	0
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (0) POST DOCTORAL SCHOLARS				0.00	0.00	0.00	0
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (2) GRADUATE STUDENTS							33,194
4. (2) UNDERGRADUATE STUDENTS							10,510
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							43,704
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							4,056
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							47,760
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							1,000
2. FOREIGN							0
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 0							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							0
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							1,000
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							1,500
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							15,935
TOTAL OTHER DIRECT COSTS							18,435
H. TOTAL DIRECT COSTS (A THROUGH G)							67,195
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
TOTAL INDIRECT COSTS (F&A)							26,655
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							93,850
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 93,850
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Duncan Sibley				FOR NSF USE ONLY			
ORG. REP. NAME* Emily Flanner				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification

OTHER PERSONNEL:

Salary support is request for a half-time graduate assistant. Responsibilities will include interviewing students while they are working on analogy assignments, scoring students assignments and interpreting the interviews and assignment scores.

Hourly student labor is also request for a graduate student to work with the CRCSTL Board of Evaluators to evaluate this project.

FRINGE BENEFITS:

MSU fringe benefits are based on a specifically identified rate for all employees. Under this system, costs are identified into four categories and accounts will be charged only to the extent that an employee receives those benefits. Categories are; Retirement; FICA; Other/Miscellaneous; and Health Costs. For additional information please refer to <http://www.cga.msu.edu/si.htm> . Summer salaries for AY appointment faculty are limited to 7.65%.

All salaries are increased by 3% annually.

MATERIALS AND SUPPLIES:

Materials and supplies category will cover interview materials and specific project expenses such as interview transcription, copy charges, long distance telephone/fax charges, etc.

INDIRECT COSTS:

MSU negotiated rate, effective 7/1/08, is 52%.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION Northwestern University				FOR NSF USE ONLY					
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dedre Gentner				PROPOSAL NO.		DURATION (months)			
				Proposed		Granted			
AWARD NO.									
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer		Funds granted by NSF (if different)	
				CAL	ACAD	SUMR			
1. Dedre Gentner - none				0.00	0.00	0.00	\$	0	\$
2.									
3.									
4.									
5.									
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00		0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00		0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)									
1. (1) POST DOCTORAL SCHOLARS				6.00	0.00	0.00		23,500	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00		0	
3. (0) GRADUATE STUDENTS								0	
4. (1) UNDERGRADUATE STUDENTS								2,400	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)								0	
6. (0) OTHER								0	
TOTAL SALARIES AND WAGES (A + B)								25,900	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)								5,523	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)								31,423	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)									
TOTAL EQUIPMENT								0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)								1,800	
2. FOREIGN								0	
F. PARTICIPANT SUPPORT COSTS									
1. STIPENDS \$ 600									
2. TRAVEL 0									
3. SUBSISTENCE 0									
4. OTHER 0									
TOTAL NUMBER OF PARTICIPANTS (50) TOTAL PARTICIPANT COSTS								600	
G. OTHER DIRECT COSTS									
1. MATERIALS AND SUPPLIES								600	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION								0	
3. CONSULTANT SERVICES								0	
4. COMPUTER SERVICES								0	
5. SUBAWARDS								0	
6. OTHER								0	
TOTAL OTHER DIRECT COSTS								600	
H. TOTAL DIRECT COSTS (A THROUGH G)								34,423	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)									
B C E G (Rate: 52.5000, Base: 33823)									
TOTAL INDIRECT COSTS (F&A)								17,757	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)								52,180	
K. RESIDUAL FUNDS								0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$	52,180	\$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$					
PI/PD NAME Dedre Gentner				FOR NSF USE ONLY					
ORG. REP. NAME* Trink newman				INDIRECT COST RATE VERIFICATION					
				Date Checked		Date Of Rate Sheet		Initials - ORG	

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0942099

SUMMARY PROPOSAL BUDGET

YEAR **2**

ORGANIZATION Northwestern University				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dedre Gentner				PROPOSAL NO.		DURATION (months)	
				Proposed		Granted	
AWARD NO.							
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	
				CAL	ACAD	SUMR	Funds granted by NSF (if different)
1. Dedre Gentner - none				0.00	0.00	0.00	\$ 0 \$
2.							
3.							
4.							
5.							
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00	0
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (1) POST DOCTORAL SCHOLARS				6.00	0.00	0.00	24,205
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (1) UNDERGRADUATE STUDENTS							2,472
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							26,677
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							5,882
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							32,559
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							1,800
2. FOREIGN							0
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 600							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS							600
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							600
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							0
TOTAL OTHER DIRECT COSTS							600
H. TOTAL DIRECT COSTS (A THROUGH G)							35,559
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) B C E G (Rate: 52.5000, Base: 34959)							
TOTAL INDIRECT COSTS (F&A)							18,353
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							53,912
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 53,912 \$
M. COST SHARING PROPOSED LEVEL \$ 0				AGREED LEVEL IF DIFFERENT \$			
PI/PD NAME Dedre Gentner				FOR NSF USE ONLY			
ORG. REP. NAME* Trink newman				INDIRECT COST RATE VERIFICATION			
		Date Checked		Date Of Rate Sheet		Initials - ORG	

2 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

0942099

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION Northwestern University				FOR NSF USE ONLY			
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Dedre Gentner				PROPOSAL NO.	DURATION (months)		
				AWARD NO.	Proposed	Granted	
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)				NSF Funded Person-months		Funds Requested By proposer	Funds granted by NSF (if different)
				CAL	ACAD	SUMR	
1. Dedre Gentner - none				0.00	0.00	0.00	\$ 0 \$
2.							
3.							
4.							
5.							
6. () OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)				0.00	0.00	0.00	0
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)				0.00	0.00	0.00	0
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)							
1. (2) POST DOCTORAL SCHOLARS				12.00	0.00	0.00	47,705
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)				0.00	0.00	0.00	0
3. (0) GRADUATE STUDENTS							0
4. (2) UNDERGRADUATE STUDENTS							4,872
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)							0
6. (0) OTHER							0
TOTAL SALARIES AND WAGES (A + B)							52,577
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)							11,405
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)							63,982
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING \$5,000.)							
TOTAL EQUIPMENT							0
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)							3,600
2. FOREIGN							0
F. PARTICIPANT SUPPORT COSTS							
1. STIPENDS \$ 1,200							
2. TRAVEL 0							
3. SUBSISTENCE 0							
4. OTHER 0							
TOTAL NUMBER OF PARTICIPANTS (50) TOTAL PARTICIPANT COSTS							1,200
G. OTHER DIRECT COSTS							
1. MATERIALS AND SUPPLIES							1,200
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION							0
3. CONSULTANT SERVICES							0
4. COMPUTER SERVICES							0
5. SUBAWARDS							0
6. OTHER							0
TOTAL OTHER DIRECT COSTS							1,200
H. TOTAL DIRECT COSTS (A THROUGH G)							69,982
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)							
TOTAL INDIRECT COSTS (F&A)							36,110
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)							106,092
K. RESIDUAL FUNDS							0
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							\$ 106,092 \$
M. COST SHARING PROPOSED LEVEL \$ 0 AGREED LEVEL IF DIFFERENT \$							
PI/PD NAME Dedre Gentner				FOR NSF USE ONLY			
ORG. REP. NAME* Trink newman				INDIRECT COST RATE VERIFICATION			
				Date Checked	Date Of Rate Sheet	Initials - ORG	

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Dedre Gentner, Northwestern University

May 21st, 2009

Budget Justification

This section summarizes how the expenditures budgeted will enable us to carry out the proposed research.

Other Professionals: We are asking for (1) part-time post doctoral candidate to develop instructional materials and assessment tools, analyze data collected from the target classes, conduct literature review to explore more ways to integrate research on analogical learning with the challenges of classroom teaching, and work with CRCSTL to devise ways to transfer research tools and findings to entry-level college classrooms

Fringe Rates:

Employee benefits have been calculated based on the following DHHS approved rates:

- 9/1/09 – 8/31/10 23.50% (estimated)
- 9/1/10 – 8/31/11 24.30% (estimated)
- 9/1/11 – 8/31/12 24.90% (estimated)

Undergraduate Students: We are requesting funds for (1) undergraduate students to work 10 hrs/week for 24 weeks during the academic year. He/she will help prepare stimuli, run subjects, and perform various other chores associated with the project. Students are exempt from fringe benefits during the academic months.

Travel: The post doctoral candidate and Prof. Gentner are requesting funds for periodic visits to Michigan to discuss research and progress with collaborators, and to present finding at conferences and meetings.

Materials and Supplies:

We are requesting funds for:

- For software and other materials necessary to carry out the proposed research
- For computers and Tablet PCs to design and conduct experiments, collect and analyze data, etc.

Other Direct Costs:

We are requesting funds:

- For subject fees. We estimate spending \$600 in years one and two to pay participants in our research studies.

F&A has been calculated on all direct costs (minus equipment and tuition) based on the following DHHS approved rates:

52.5% MTDC 9/1/08 - 8/31/11

52.5% MTDC 9/1/11 and thereafter (provisional)

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal. *If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Investigator: **Duncan Sibley**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Source of Support: **NSF**

Total Award Amount: **\$93,850**

Total Award Period Covered: **1/1/10-12/31/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **1.0**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Diagnostic question clusters: Development and testing in introductory geology and biology

Source of Support: **NSF**

Total Award Amount: **\$491,606**

Total Award Period Covered: **9/15/03-8/31/09**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.25**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Analyzing constructed responses: Using linguistic software to understand students conceptions in science

Source of Support: **NSF**

Total Award Amount: **\$150,000**

Total Award Period Covered: **8/1/08-7/31/10**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal: **1.0**

Acad:

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

A framework for reasoning in cell biology courses

Source of Support: **NSF**

Total Award Amount: **\$150,000**

Total Award Period Covered: **1/15/08-12/31/09**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.25**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Robert Noyce Scholars Phase II: Preparing teachers for a new era

Source of Support: **NSF**

Total Award Amount: **\$500,000**

Total Award Period Covered: **8/15/08-7/31/12**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal: **0.5**

Acad:

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.			
Investigator: Julie C. Libarkin		Other agencies (including NSF) to which this proposal has been/will be submitted.	
Support: <input type="checkbox"/> Current <input checked="" type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Are We Heading in the Right Direction? An Evaluation of Learning Goals for General Education Earth Systems Science Courses Source of Support: NSF-CCLI Total Award Amount: \$196,646 Total Award Period Covered: 09/01/09 to 08/31/11 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:			
Support: <input type="checkbox"/> Current <input checked="" type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Collaborative Research: Building Global Climate Change Literacy Through Analogical Reasoning Source of Support: NSF-CCLI Total Award Amount: \$200,000 Total Award Period Covered: 11/01/09 to 10/31/11 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 0.5 Acad: Sumr:			
Support: <input type="checkbox"/> Current <input checked="" type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Collaborative Research: Confronting the Challenges of Climate Literacy. Source of Support: NSF-DRK12 Total Award Amount: \$575,000 Total Award Period Covered: 9/1/2009 - 8/30/2013 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 0.5 Acad: Sumr:			
Investigator: Julie C. Libarkin		Other agencies (including NSF) to which this proposal has been/will be submitted.	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Investigation of alternative conceptions about Plate Tectonics across the expert-novice continuum – when a well-known theory isn't so well known Source of Support: NSF-CCLI Total Award Amount: \$199,471 Total Award Period Covered: 01/15/09 to 12/31/10 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 0.5 Acad: Sumr:			
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Collaborative Research: Learning across the Expert-Novice Continuum: Cognition in the Geosciences Source of Support: NSF-REESE Total Award Amount: \$430,000 Total Award Period Covered: 04/01/09 – 03/31/12 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:			
*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.			



Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.			
Investigator: Julie C. Libarkin		Other agencies (including NSF) to which this proposal has been/will be submitted.	
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Investigation of alternative conceptions about Plate Tectonics across the expert-novice continuum – when a well-known theory isn't so well known Source of Support: NSF-CCLI Total Award Amount: \$200,000 Total Award Period Covered: 01/01/09 to 12/31/10 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 0.5 Acad: Sumr:			
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Collaborative Research: Community Development of an expanded Geoscience Concept Inventory: A webcenter for question generation, validation, and online testing. Source of Support: NSF - DUE Total Award Amount: \$331,008 Total Award Period Covered: 9/01/07 – 8/31/10 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:			
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Collaborative Research: Evaluating student learning in Geoscience curricula that employ conceptests using electronic student response systems Source of Support: University of Akron (subcontract on NSF grant) Total Award Amount: \$ 77,549 Total Award Period Covered: 9/01/07 – 8/31/10 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 1.0 Acad: Sumr:			
Support: <input checked="" type="checkbox"/> Current <input type="checkbox"/> Pending <input type="checkbox"/> Submission Planned in Near Future <input type="checkbox"/> *Transfer of Support Project/Proposal Title: Facilitating a Deeper Understanding of Change in the Earth System on Multiple Time Scales Source of Support: TERC (consultant on NSF grant) Total Award Amount: \$7500 Total Award Period Covered: 9/01/08 – 8/31/10 Location of Project: Michigan State University Person-Months Per Year Committed to the Project. Cal: 0.25 Acad: Sumr:			
*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.			

NSF Form 1239 (10/99)

USE ADDITIONAL SHEETS AS NECESSARY



Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal. *If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Investigator: **Mark Urban-Lurain**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Source of Support: **NSF**

Total Award Amount: **\$93,850**

Total Award Period Covered: **1/1/10-12/31/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.5**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

First III: Faculty institutes for reforming science teaching: Developing the scholarship of scientific teaching

Source of Support: **NSF**

Total Award Amount: **\$418,984**

Total Award Period Covered: **1/1/07-12/31/09**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **1.0**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

CPATH CB: Computing and undergraduate engineering: A collaborative process to align computing education with engineering

Source of Support: **NSF**

Total Award Amount: **\$449,859**

Total Award Period Covered: **9/1/07-8/31/09**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad:

Sumr: **1.0**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Reforming introductory biology at MSU - Does it make a difference

Source of Support: **NSF**

Total Award Amount: **\$146,341**

Total Award Period Covered: **2/1/08-1/31/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.2**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Analyzing constructed responses: using linguistic software to understand students conceptions in science

Source of Support: **NSF**

Total Award Amount: **\$150,000**

Total Award Period Covered: **8/1/08-7/31/10**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.9**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal. *If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Investigator: **Mark Urban-Lurain**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

A framework for reasoning in cell biology courses

Source of Support: **NSF**

Total Award Amount: **\$200,000**

Total Award Period Covered: **1/15/08-12/31/09**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.2**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

EEES: Engaging early engineering students to expand numbers of degree recipients

Source of Support: **NSF**

Total Award Amount: **\$1,427,298**

Total Award Period Covered: **7/1/08-6/30/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad:

Sumr: **1.0**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Simplifying complexity: Analyzing students' model of biological systems

Source of Support: **NSF**

Total Award Amount: **\$533,261**

Total Award Period Covered: **6/1/09-5/31/12**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **.5**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Building computational expertise through an integrated spiral chemical engineering curriculum

Source of Support: **NSF**

Total Award Amount: **\$398,775**

Total Award Period Covered: **8/16/09-8/15/12**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **.2**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

CPACE II: Implementing constituency-driven curricular change that integrates computational thinking across engineering disciplines

Source of Support: **NSF**

Total Award Amount: **\$799,796**

Total Award Period Covered: **8/16/09 - 8/15/12**

Location of Project: **MSU**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **1.0**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal. *If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Investigator: **Mark Urban-Lurain**

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Concurrent validation of multiple-choice exams in a large biochemistry course

Source of Support: **NIH**

Total Award Amount: **\$329,277**

Total Award Period Covered: **9/30/09-9/29/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.5**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Improving the efficacy of STEM teaching and learning: Automated analysis of open response assessments

Source of Support: **NIH**

Total Award Amount: **\$999,635**

Total Award Period Covered: **9/30/09-9/29/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **1.0**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Collaborative Research: Examining Lexical Ambiguity in Statistics Teaching in College (ELASTic)

Source of Support: **NSF**

Total Award Amount: **\$134,653**

Total Award Period Covered: **1/01/10-12/31/11**

Location of Project: **Michigan State University**

Person-Months Per Year Committed to the Project.

Cal:

Acad: **0.2**

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:

Total Award Amount: \$

Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project.

Cal:

Acad:

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:

Source of Support:

Total Award Amount: \$

Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project.

Cal:

Acad:

Sumr:

Other agencies (including NSF) to which this proposal has been/will be submitted.

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Dedre Gentner, Northwestern University

May 21st, 2009

Current Support

National Science Foundation:

Spatial Intelligence and Learning Center

SBE-0541957

\$5,223,573 to date, Northwestern University

2006 – 2011

Person months:

Academic: .40

Summer: 1.1

Office for Naval Research:

Analogical Reasoning and Case- Based Instruction (with Ken Forbus)

N00014-08-1-0040

\$1,811,314

2008 – 2012

Person months:

Academic: 0

Summer: 1

Pending Support

National Science Foundation:

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Solicitation 09-529

\$106,092

2010 – 2011

Person months:

Academic: 0.09

Summer: 0

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory:

Clinical:

Animal:

Computer:

Office:

Other:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

No special equipment or facilities are necessary

Collaborative Research: Building Global Climate Change Literacy through Analogical Reasoning

Dedre Gentner, Northwestern University

May 21st, 2009

Facilities, equipment, and other resources

To facilitate the research, Northwestern University has provided Professor Gentner with a laboratory that includes excellent capabilities for analogical research. Laboratory space for adult studies include a room with five standard testing booths equipped with computers for automated data collection. In addition, there are multiple computer-equipped rooms for coding, stimulus preparation, performing analyses and running group studies.